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(71) Applicant: Nippon Antena Kabushiki Kaisha
Tokyo 116-0011 (JP)

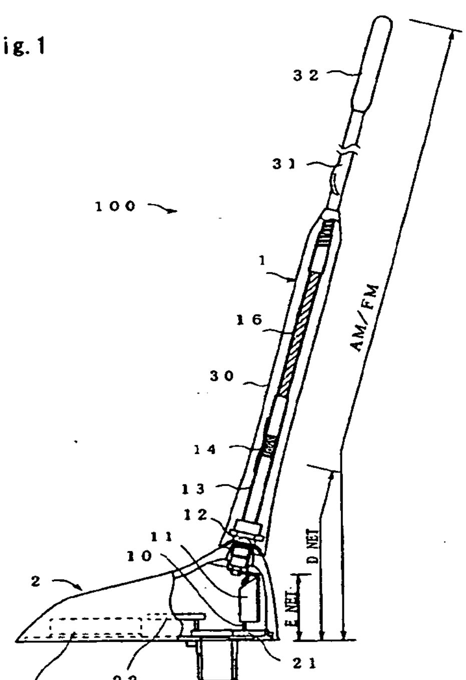
(72) Inventors:
- SHIMIZU, Hiroshi
Gyoda-shi, Saitama 361-0037 (JP)
- KADOTA, Yoshio,
c/o Nippon Antena Kabushiki Kaisha
Warabi-shi, Saitama 335-0001 (JP)

(74) Representative: Grünecker, Kinkeldey,
Stockmair & Schwanhäusser Anwaltssozietät
Maximilianstrasse 58
80538 München (DE)

(54) MULTI-FREQUENCY ANTENNA

(57) A D-net antenna is split in two, and one part thereof is provided as a D-net element 13 in an antenna element 1. The other element thereof is accommodated inside the cover section 2 as a lower element 10. An E-net element 11 is connected to the top end of the lower element 10. This E-net element 11 has a rectangular radiating surface, and has virtually omnidirectional characteristics in the horizontal plane. The antenna element 1 is installed detachably to the cover section 2, and when it is installed thereon, the D-net element 13 and the lower element 10 become mutually connected. Thereby, a multi-frequency antenna operating across two different broad frequency bands is obtained.

Fig. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a multi-frequency aerial operating in a first frequency band and a second frequency band, and it is suitably applied to a multi-frequency antenna for a vehicle capable of receiving a first mobile radio band, a second mobile radio band, an FM/AM radio and, and GPS band.

BACKGROUND ART

[0002] There are various types of antenna that are installed on vehicles, but conventionally, roof vehicles which are installed on the vehicle roof have been preferred since they enable reception sensitivity to be improved by means of the antenna being installed of the roof which is the highest position on the vehicle. Moreover, since an FM/AM radio is generally fitted in a vehicle, it is convenient to use an antenna capable of receiving both FM and AM radio bands, and hence roof antennas which are capable of receiving two radio bands conjointly have been widespread.

[0003] Moreover, in recent years, car navigation systems using GPS (Global Positioning System), and mobile telephones, have become increasingly popular, and GPS antennas for car navigation systems, and mobile phone antennas for mobile phones, have been installed on vehicles.

[0004] Moreover, if the vehicle comprises a keyless entry system wherein the door locking and unlocking actions are operated remotely by wireless, then a keyless entry antenna is installed on the vehicle.

[0005] However, installing various types of antennas of these kinds independently on a vehicle not only involves design problems, but also complicates the maintenance and installation tasks, and the like, and hence a multi-frequency antenna which receives a mobile phone band, FM/AM radio bands, GPS band and keyless entry band, and the like, in a single antenna, has been proposed.

[0006] A multi-frequency antenna disclosed in Japanese Patent Laid-open No.H6-132714 is known as one example of this type of multi-frequency antenna. This multi-frequency antenna is constituted by a retractable rod antenna forming a combined three-wave antenna for receiving a mobile phone band, FM radio band, and AM radio band, a planar radiating element forming a GPS antenna for receiving GPS signals, and a loop radiating element forming a keyless entry antenna for receiving keyless entry signals.

[0007] These respective antennas are installed on the upper face of a main body, and a metal plate is provided in the upper portion of the main body, the planar radiating body and the loop radiating body being formed on this plate via an inductive layer. Since the plate forms a ground plane, the planar radiating element and the loop radiating element operate as microstrip antennas. Furthermore, a protective cover is formed over the planar radiating element and loop radiating element.

[0008] Since a multi-frequency antenna of this kind comprises a retractable rod antenna, it is necessary to provide a space for accommodating the rod antenna when it is installed. Therefore, whilst it is possible to install the multi-frequency antenna on the boot lid or wing of the vehicle where such space can be formed, it cannot be installed on the roof, which is the optimum position for situating an antenna, since this does not have the required accommodating space. In this case, if the multi-frequency antenna is installed on the boot lid or wing of the vehicle, then since the angle of inclination of the GPS satellite is in many cases a low angle of inclination, there is a risk that the electromagnetic waves from the satellite may be shielded by the body of the vehicle, depending on the position of the GPS satellite. Therefore, a multi-frequency antenna designed to resolve this problem is disclosed in Japanese Patent Laid-open No. H10-93327.

[0009] This multi-frequency antenna is constituted by an antenna element designed to resonate at multiple frequencies by being provided with a trap coil, and a cover section having a built-in regulating circuit board, or the like, on which this antenna element is installed. By fixing this cover section to the roof, the multi-frequency antenna can be installed on the roof.

[0010] Generally, a plurality of frequency bands are assigned for use by mobile phones. For example, in the PDC (Personal Digital Cellular telecommunication system) used in Japan, the 800 MHz band (810 MHz - 956 MHz) and 1.4 GHz band (1429 MHz - 1501 MHz) are allocated. In Europe, the 800 MHz (870 MHz - 960 MHz) GSM (Global System for Mobile communications) and the 1.7 GHz (1710 MHz - 1880 MHz) DCS (Digital Cellular System) are employed. To operate an antenna in a plurality of operating frequencies of this kind, antennas which operate in the respective frequency bands are provided, but generally, two antennas are connected by means of a choke coil so that they mutually affect the operation of the other.

[0011] However, in a choke coil, such as a trap coil, or the like, it is difficult to separate signals across a broad frequency range. In other words, even if a choke coil is provided between antennas operating in respective frequency bands, if the frequency bandwidths are large, as in mobile telephone bands, then it is not possible to make the respective antennas work independently across these frequency bands, and hence there is a problem in that the antennas affect each other and cannot be made to operate satisfactorily.

DISCLOSURE OF THE INVENTION

[0012] It is an object of the present invention to provide a multi-frequency antenna of a novel composition which operates across two different broad frequency

bands, and in order to achieve the aforementioned object, the antenna comprises a first element operating in a first frequency band, and a second element having a rectangular extended radiating surface operating in a second frequency band which is higher than the first frequency band, connected to an intermediate region of the first element. The operating principles of the multi-frequency antenna of the present invention according to this composition are not clear, but the antenna are able to operate independently without mutual adverse effects, even if the first frequency band and second frequency band are broad frequency bands, such as mobile phone bands. Since the second element has an extended radiating surface, it is possible to achieve virtually omnidirectional characteristics in the horizontal plane.

[0013] Moreover, in the multi-frequency antenna according to the present invention, the first frequency band is taken as a first mobile radio band, and the second frequency band is taken as a second mobile radio band, being a frequency band approximately twice as high as the first mobile radio band.

[0014] Furthermore, if the first element is split in two, and the lower element of the split first element is accommodated inside a cover section, whilst the second element is also accommodated inside the cover section, then a compact multi-frequency antenna can be obtained. It is possible to make a circuit board incorporating a frequency divider, and the like, accommodatable in the space inside the cover section.

[0015] Moreover, by providing an element operating in a much lower frequency band, such as an AM/FM band, via a choke coil, at the top end of the first element, then it is possible to obtain a multi-frequency antenna operating at three frequencies or more. Furthermore, if a GPS antenna unit is provided in the accommodating space inside the cover, then GPS signal can also be received, without adversely affecting the other antennas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 is a diagram showing a partial sectional view of the composition of a first embodiment of a multi-frequency antenna according to the present invention;

Fig. 2 is a diagram showing a enlarged partial view of a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 3 is a diagram illustrating the composition of a lower element of a split D-net element, and an E-net element, in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 4 is a diagram illustrating the detailed composition of a lower element of a split D-net element of a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 5 is a diagram showing the detailed composition of the E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 6 is a diagram showing the general composition of an E-net element connected to a D-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 7 is a diagram showing impedance characteristics in a D-net frequency band when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 8 is a diagram showing VSWR characteristics in a D-net frequency band when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 9 is a diagram showing impedance characteristics in an E-net frequency band when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 10 is a diagram showing VSWR characteristics in a E-net frequency band when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 11 is a diagram showing directionality characteristics and a measurement state, at a lowest D-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 12 is a diagram showing directionality characteristics in a horizontal plane at a middle and a highest D-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 13 is a diagram showing directionality characteristics in a horizontal plane at a lowest and a middle E-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 14 is a diagram showing directionality characteristics in a horizontal plane, at a highest E-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 15 is a diagram illustrating the measurement state of directionality characteristics in a vertical

plane, when a multi-frequency antenna according to a first embodiment of the present invention is stood upright;

Fig. 16 is a diagram showing directionality characteristics in a vertical plane at a lowest and a middle D-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 17 is a diagram showing directionality characteristics in a vertical plane at a lowest E-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 18 is a diagram showing directionality characteristics in a vertical plane at a middle and a highest E-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 19 is a diagram illustrating the measurement state of directionality characteristics in a vertical plane, when a multi-frequency antenna according to a first embodiment of the present invention is inclined;

Fig. 20 is a diagram showing directionality characteristics in a vertical plane at a lowest D-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 21 is a diagram showing directionality characteristics in a vertical plane at a middle and a highest D-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 22 is a diagram showing directionality characteristics in a vertical plane at a lowest and a middle E-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 23 is a diagram showing directionality characteristics in a vertical plane at a highest E-net frequency, when particular constants are used for the dimensions of a D-net element and E-net element in a multi-frequency antenna according to a first embodiment of the present invention;

Fig. 24 is a diagram showing a partial sectional view of a composition of a second embodiment of a multi-frequency antenna according to the present invention;

Fig. 25 is a diagram showing a partial enlargement of a multi-frequency antenna according to a second embodiment according to the present invention;

Fig. 26 is a diagram showing the composition of a lower element of a split D-net element, and an E-net element, in a multi-frequency antenna according to a second embodiment according to the present invention;

Fig. 27 is a diagram showing the detailed composition of a lower element of a split D-net element in a multi-frequency antenna according to a second embodiment according to the present invention;

Fig. 28 is a diagram showing the detailed composition of an E-net element in a multi-frequency antenna according to a second embodiment according to the present invention; and

Fig. 29 is a diagram showing the general composition of an E-net element connected to a D-net element in a multi-frequency antenna according to a second embodiment according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0017] A partial sectional view of the composition of a first embodiment of a multi-frequency antenna according to the present invention is illustrated in Fig. 1, and an enlarged view thereof is illustrated in Fig. 2.

[0018] As shown in these diagrams, the multi-frequency antenna 100 relating to the first embodiment of the present invention is constituted by a linear antenna element 1, and a cover section 2 made from resin, on which the antenna element 1 is installed detachably. The antenna element 1 comprises a helical element section 31 formed in a helical shape, and an antenna top 32 provided at the upper end of this helical element section 31. Moreover, a moulded antenna base section 30 is provided on the lower end of the helical element section 31. A bendable elastic element section 16 connected to the lower end of the helical element section 31, and a choke coil 14 of which one end if connected to the lower end of the elastic element section 16, are provided inside the antenna base section 30. Moreover, the other end of the choke coil 14 is connected to a D-net element 13 which corresponds to an upper D-net element, and a fixing screw 12 is provided on the lower end of the D-net element 13.

[0019] Here, "D-net" indicates a first mobile phone band based on the aforementioned GSM system, and "E-net", which is mentioned hereinafter, indicates a second mobile phone band based on the aforementioned DCS system.

[0020] Incidentally, wind noise preventing means wound in a coil shape is also provided on the helical element section 31. Moreover, the elastic element section 16 serves to prevent the antenna element 1 from bending and snapping when a lateral load is applied thereto. This elastic element section 16 can be constituted by an elastic wire cable or coil spring.

[0021] A metal base 25 is fitted into the lower face of the cover section 2 which is formed by resin moulding, and a cylindrical installation section 24 for installation

onto the roof, or the like, of a vehicle is formed projecting from this base 25. A screw thread is cut into the outer circumference of the base 25, and signal cables and power cables leading from inside the cover section 2 can be inserted through a clearance hole formed on the inner side thereof.

[0022] This cover section 2 accommodates a lower element 10 for D-net use, and an element 11 for E-net use formed in such a manner that it has a rectangular radiating surface connecting to the vicinity of the upper end of the lower element 10. The composition of the D-net lower element 10 and the E-net element 11 is illustrated in Fig. 3. Moreover, a screw receiving section 2a for receiving a fixing screw section 12 provided at the lower end of the antenna base section 30 is provided on the upper face of the cover section 2. A screw thread is cut into the inner circumference of this metal screw receiving section 2a, which is formed as an insert in the cover section 2. At the lower end of the screw receiving section 2a there is provided a connecting section 10a, formed on the front end of the lower element 10 and into which a connecting insertion section 12a formed on the front end of the fixing screw section 12 is screwed. In other words, by screwing the fixing screw section 12 provided on the antenna base section 30 into the screw receiving section 2a, the connection section I0 and the D-net element 13 in the antenna base section 30 become electrically connected by means of the fixing screw section 12. Thereby, the D-net element 13 forming one element of the split D-net antenna, and the lower element 10 forming the other element thereof, are connected.

[0023] A circuit board 21 is soldered to the lower end of the lower element 10, and filter for dividing waves between a D-net and E-net mobile phone band and an AM/FM band is provided in this circuit board 21. The AM/FM band signal divided thereby is amplified by an amplifying circuit incorporated into an amplifying circuit board 22 accommodated within the cover section 2. Moreover, a GPS unit 23 consisting of a GPS antenna and a converter section for converting received GPS signals to intermediate frequency signals is accommodated inside the cover section 2. In this case, since the E net element 11 is designed so as to be located at the rear face of the lower element 10, it does not affect the low inclination angle directionality characteristics of the GPS antenna in the GPS unit 23. Moreover, D-net and E-net mobile phone band signals are extracted from a signal cable connected to the circuit board 21, whilst AM/FM signal band signals are extracted from the amplifying circuit board 22, and GPS signals converted to intermediate frequency signals are extracted from a signal cable connected to the GPS unit 23. These cables are led out from the cover section 2 by passing through the inside of the installation section 24, and are then connected to corresponding devices located inside the vehicle.

[0024] The composition of the D-net lower element 10 and the E-net element 11 is illustrated in Fig. 3. The composition of the lower element 10 is described hereinafter, but it is plate-shaped having a front end section bent to an approximate L shape in cross section by processing a metal plate, and a screw thread section 10d into which the connecting insertion section 12a is screwed is formed in approximately the centre of the connecting section 10a formed at the bent front end section thereof. Moreover, a soldering piece 10b for soldering to the circuit board 21 is formed at the lower end of the lower element 10.

[0025] Furthermore, the E-net element 11 is formed so as to have an approximately rectangular radiating surface, by processing a metal plate, a connecting piece extending from approximately the centre of one edge thereof being bent in a square U shape, and a holding piece 11a being formed on the front end thereof. This holding piece 11a is inserted into a cutaway window formed in the upper portion of the main member of the lower element 10, and it holds the lower element 10 on either side thereof. By soldering the portion held in this way, the E-net element 11 is affixed to the lower element 10 and also electrically connected thereto. As described hereinafter, this E-net element 11 has an enlarged radiating surface having an approximately rectangular shape in order that it has virtually omnidirectional characteristics in the horizontal plane. Furthermore, either end section of the E net element 11 is bent slightly forwards, and both corner regions of the upper edge thereof are cut away by processing. This is in order that the E-net element 11 can be accommodated in a narrow accommodating space formed by the rear face of the lower element 10 and the side wall of the cover section 2. The bending of the E-net element 11 and the removal of the two corner regions thereof do not affect the directionality characteristics thereof in the horizontal plane.

[0026] In the multi-frequency antenna 100 according to the first embodiment of the present invention, by means of the aforementioned composition, the separated D-net element 13 and D-net lower element 10 are connected when the antenna element 1 is screwed into the cover section 2. In other words, in the multi-frequency antenna 100 according to the first embodiment of the present invention, as illustrated in Fig. 1, the D-net antenna is an antenna which operates in a range from the circuit board 21 to the lower end of the choke coil 14. Moreover, the E-net antenna is an antenna which operates in a range from the circuit board 21 to the upper end of the lower element 10. Moreover, the AM/FM band antenna is an antenna which operates in the range from the circuit board 21 to the antenna tip 32. However, it does not resonate in the AM band.

[0027] Next, the detailed composition of the lower element 10 and the E-net element 11 in the multi-frequency antenna 100 in the first embodiment of the present invention will be described with reference to Fig. 4 and Fig. 5.

[0028] Fig. 4 shows the detailed composition of the lower element 10: Fig. 4(a) is a front view of a lower element 10; Fig. 4(b) is a side view thereof; Fig. 4(c) is

a rear face view thereof; and Fig. 4(d) is a lower face view thereof.

[0029] As illustrated in these diagrams, the lower element 10 has a plate shape, the front end section thereof being bent to an approximate L shape in cross-section, by processing a metal plate. The bent front end section thereof is taken as a connecting section 10a, and a screw thread section 10d into which the connecting insertion section 12a is screwed is formed in the approximate centre of this connecting section 10a. Furthermore, a taper is applied to the main piece 10c extending downwards from the end of the connecting section 10a, such that it has a narrower width at the lower end thereof, and the upper portion thereof is bent slightly towards to the rear side. A soldering piece 10b for soldering to the circuit board 21 is formed at the lower end of the main piece 10c. Moreover, a portion of the upper part of the main piece 10c is cutaway to form cutaway window 10e.

[0030] Fig. 5 shows the detailed composition of the E-net element 11: Fig. 5(a) is a front view of the E-net element 11; Fig. 5(b) is a side view thereof; and Fig. 5(c) is a lower side view thereof.

[0031] As shown in these diagrams, the E-net element 11 is formed having an enlarged radiating surface having an approximately rectangular shape, by processing a metal plate, end pieces 11d, lie on either side being bent slightly forwards on the approximately rectangular radiating surface, and both corner sections of the upper edge thereof being cut away by processing. Moreover, a connecting piece 11f and bent piece 11b are formed by extending a portion from approximately the centre of the upper edge of the element 11, and bending it into a square U shape. A holding piece 11a is formed by cutting one portion of the front edge of the bent piece 11b

[0032] This holding piece 11a is inserted to sit either side of the cutaway window 10e forming on the upper portion of the main piece 10c of the lower element 10. When thus held, the E-net element 11 can be affixed to the lower element 10, and mutual electrical connection can be established, by soldering the holding piece 11a about the periphery of the cutaway window 10e. If the bend angle of the central piece 11c with respect to the connecting piece 11f is set to greater than 90° when the E-net element 11 is affixed to the lower element 10, then the lower element 10 and the centre piece 11c of the E-net element 11 will be positioned approximately in parallel.

[0033] The multi-frequency antenna 100 according to the first embodiment of the present invention operates simultaneously as a four-frequency antenna for D-net and E-net mobile phone bands, and an AM/FM band, and furthermore, GPS signals can be received by means of a separately provided GPS unit 23. In this case, if no AM/FM band devices are provided and hence the AM/FM antenna is obsolete, then it is possible to accommodate only the D-net element 13, which is one of the split elements, inside the antenna base section 30. In this way, the multi-frequency antenna 100 according to the first embodiment of the present invention may be a multi-frequency antenna that operates only in the D-net and E-net by means of the antenna element 1. In this case, naturally, the length of the antenna element 1 can be shorted accordingly.

[0034] Next, the composition of the D-net and E-net antenna in the composition in Fig. 1 will be described, by the following explanation of the theoretical composition of an antenna which is used as a multi-frequency antenna operating only in the D-net and E-net in this manner.

[0035] Fig. 6(a) shows the theoretical composition of an antenna operating only in the D-net and E-net, relating to the multi-frequency antenna 100 according to the first embodiment of the present invention.

[0036] As shown in Fig. 6(a), the split D-net antenna is a linear antenna of length L1, comprising an upper portion forming a D-net element 13, and a lower portion forming a lower element 10 of length L2. Moreover, the D-net antenna composed in this manner projects in a slightly inclined manner at an angle of $\theta 1$ with respect to the horizontal plane. An E-net element 11 having a length L3 is connected to the region where the D-net element 13 joins with the lower element 10. The E-net element 11 is disposed approximately in parallel to the lower element 10, separated therefrom by the length L4 of the connecting piece 11f described above. The front end of this connecting piece 11f is connected to an intermediate part of the D-net antenna constituted by the D-net element 13 and the lower element 10. The composition of the E-net element 11 is as illustrated in Fig. 5, and the approximate form thereof is illustrated in Figs. 6(b) and (c), the width of the rectangular shape forming the enlarged radiating surface being taken as W1. The lower end of the lower element 10 forms an electricity supply point for the D-net antenna and the E-net element 11, as illustrated in the diagrams.

[0037] The dimensions illustrated in Fig. 6, namely, the length L1 of the D-net antenna constituted by the D-net element 13 and lower element 10, the length L2 of the lower element 10, the length L3 and width W1 of the E-net element, and the interval L4 between the D-net antenna and the E-net element 11, are determined according to the frequency values of the first frequency band for the D-net and the second frequency band for the E-net, and the angle $\theta 1$ used. For example, if the angle $\theta 1$ is approximately 76°, then the taking the wavelength at the central frequency of the D-net 915 MHz as $\lambda 1$ (327.87 mm) and the wavelength at the central frequency of the E-net 1795 MHz as $\lambda 2$ (167.23 mm), the length L1 of the D-net antenna can be taken as approximately 0.202 $\lambda 1$, the length L2 of the lower element 10 as approximately 0.136 $\lambda 2$, the length L3 of the E-net element 11 as approximately 0.102 $\lambda 2$, the width W1 thereof as approximately 0.162 $\lambda 2$, and the interval L4 between the D-net antenna and the E-net antenna 11,

approximately 0.021 λ2.

[0038] Fig. 7 and Fig. 9 show impedance characteristics for a multi-frequency antenna 100 according to the first embodiment of the present invention as illustrated in Fig. 1, when the aforementioned constants are used for the dimensions of the lengths, width and interval of the split D-net element 13 and lower element 10, and the E-net element 11, whilst Fig. 8 and Fig. 10 show VSWR characteristics for same.

[0039] Fig. 7 illustrates impedance characteristics for the D-net 800 MHz band (870 MHz - 960 MHz), and an impedance value of the order of 50 Ω is obtained for this 870 MHz - 960 MH_z frequency band. 50 Ω is the impedance value to be matched to. Moreover, Fig. 9 shows impedance characteristics in the E-net 1.7 GHz band (1710 MHz - 1880 MHz), and from the lower frequency region to beyond the central frequency region of this 1710 MH_z- 1880 MHz band, an impedance of the order of 50 Ω is obtained.

[0040] Furthermore, Fig. 8 shows VSWR characteristics for the D-net 800 MHz band (870 MHz - 960 MHz), and a good VSWR value of approximately 1.8 or less is achieved in this 870 MHz - 960 MHz frequency band. Fig. 10 shows VSWR characteristics for the E-net 1.7 GHz band (1710 MHz - 1880 MHz), and a VSWR value of approximately 2.0 or less is achieved in this 1710 MHz - 1880 MHz frequency band, and in particular, a good VSWR value of approximately 1.5 or lower is' obtained from the lower frequency region to beyond the central frequency region of this band. In this case, even if the E-net element 11 is removed, the characteristics of the D-net antenna comprising the D-net element 13 and the lower element 10 are not significantly altered, and hence the D-net antenna and the E-net antenna are able to operate independently of each other. At present, the operational principles thereof are not certain.

[0041] Next, Fig. 11 to Fig. 14 show directionality characteristics within a horizontal plane for a multi-frequency antenna 100 according to the first embodiment of the present invention as illustrated in Fig. 1, in a case where the aforementioned constants are used for the dimensions of the lengths, width and interval of the D-net element 13, lower element 10 and E-net element 11.

[0042] Fig. 11(a) is a diagram illustrating a measurement state of the multi-frequency antenna 100 positioned on a ground plane 50 of sufficient surface area, and showing references angle in the horizontal direction, which correspond to the angles of the directionality characteristics in the horizontal plane described hereinafter.

[0043] Fig. 11(b) illustrates the directionality characteristics in the horizontal plane of a multi-frequency antenna 100 at the lowest frequency f = 870 MHz of the D-net frequency band. As shown in this diagram, virtually omnidirectional characteristics are obtained. In this case, the gain of the multi-frequency antenna 100 is approximately +0.94 dB compared to a λ/4 whip antenna.

[0044] Fig. 12(a) shows directionality characteristics in a horizontal plane of a multi-frequency antenna 100 at the middle frequency f = 915 MHz of the D-net frequency band. As shown in this diagram, virtually omnidirectional characteristics are obtained. In this case, the gain of the multi-frequency antenna 100 is approximately + 0.5 dB compared to a λ/4 whip antenna.

[0045] Fig. 12(b) shows directionality characteristics in a horizontal plane of a multi-frequency antenna 100 at the highest frequency f = 960 MHz of the D-net frequency band. As shown in the diagram, although the level declines slightly in the -30° direction, virtually omnidirectional characteristics are obtained. In this case, the gain of the multi-frequency antenna 100 is approximately + 0.35 dB compared to a λ/4 whip antenna.

[0046] Fig. 13(a) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the lowest frequency f = 1710 MHz of the E-net frequency band. As this diagram shows, although the level is lower than the D-net, virtually omnidirectional characteristics are obtained. In this case, the gain of the multi-frequency antenna 100 is approximately - 0.8 dB compared to a λ/4 whip antenna.

[0047] Fig. 13(b) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the middle frequency f = 1795 MHz of the E-net frequency band. As shown in this diagram, virtually omnidirectional characteristics are obtained. In this case, the gain of the multi-frequency antenna 100 is approximately - 0.6 dB compared to a λ/4 whip antenna.

[0048] Fig. 14 shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the highest frequency f = 1880 MHz of the E-net frequency band. As this diagram shows, almost the same level is achieved as for the D-net, and virtually omnidirectional characteristics are obtained. In this case, the gain of the multi-frequency antenna 100 is approximately + 0.3 dB compared to a λ/4 whip antenna.

[0049] Next, Fig. 16 to Fig. 18 show directionality characteristics in a vertical plane of a perpendicularly standing multi-frequency antenna 100, in a case where the aforementioned constants are used for the dimensions of the lengths, width and interval of the D-net element 13, lower element 10 and E-net element 11 in a multi-frequency antenna 100 according to the first embodiment of the present invention illustrated in Fig. 1. Furthermore, Fig. 15 is a diagram illustrating a measurement state of the multi-frequency antenna 100 positioned perpendicularly with respect to a ground plane 50 of sufficient surface area, and showing reference angles in the vertical direction, which correspond to the angles of the directionality characteristics in the vertical plane described hereinafter.

[0050] Fig. 16(a) shows directionality characteristics in a vertical plane for a multi-frequency antenna 100 at the lowest frequency f = 870 MHz of the D-net frequency band. As shown in this diagram, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately ±60°. In this

case, the gain of the multi-frequency antenna 100 is approximately + 1.65 dB compared to a dipole antenna.

[0051] Fig. 16(b) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the middle frequency f = 915 MHz of the D-net frequency band. As shown in this diagram, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately ±60°. In this case, the gain of the multi-frequency antenna 100 is approximately + 0.55 dB compared to a dipole antenna.

[0052] Fig. 17(a) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the highest frequency f = 960 MHz of the D-net frequency band. As shown in this diagram, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately ±60°. In this case, the gain of the multi-frequency antenna 100 is approximately + 1.1 dB compared to a dipole antenna.

[0053] Fig. 17(b) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the lowest frequency f = 1710 MHz of the E-net frequency band. As shown in this diagram, although the main beam width is narrower than for the D-net, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately ±60°. In this case, the gain of the multi-frequency antenna 100 is approximately + 3.98 dB compared to a dipole antenna.

[0054] Fig. 18(a) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the middle frequency f = 1795 MHz of the E-net frequency band. As shown in this diagram, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately ±60°. In this case, the gain of the multi-frequency antenna 100 is approximately + 0.04 dB compared to a dipole antenna.

[0055] Fig. 18(b) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the highest frequency f = 1880 MHz of the E-net frequency band. As shown in this diagram, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately +70° and -65°. In this case, the gain of the multi-frequency antenna 100 is approximately + 2.65 dB compared to a dipole antenna.

[0056] Next, Fig. 20 to Fig. 23 show directionality characteristics in a vertical plane of an inclined multi-frequency antenna 100, in a case where the aforementioned constants are used for the dimensions of the lengths, width and interval of the D-net element 13, lower element 10 and E-net element 11 in a multi-frequency antenna 100 according to the first embodiment of the present invention illustrated in Fig. 1. Furthermore, Fig. 19 is a diagram illustrating a measurement state of the multi-frequency antenna 100 positioned in an inclined position with respect to a ground plane 50 of sufficient surface area, and showing reference angles in the vertical direction, which correspond to the angles of the directionality characteristics in the vertical plane described hereinafter.

[0057] Fig. 20 shows directionality characteristics in a vertical plane for a multi-frequency antenna 100 at the lowest frequency f = 870 MHz of the D-net frequency band. As shown in this diagram, although there is a slight level disparity between the plus angle direction and the minus angle direction, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately ±60°. In this case, the gain of the multi-frequency antenna 100 is approximately + 1.67 dB compared to a dipole antenna.

[0058] Fig. 21(a) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the middle frequency f = 915 MHz of the D-net frequency band. As shown in this diagram, although there is a slight level disparity between the plus angle direction and the minus angle direction, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately ±60°. In this case, the gain of the multi-frequency antenna 100 is approximately + 0.47 dB compared to a dipole antenna.

[0059] Fig. 21(b) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the highest frequency f = 960 MHz of the D-net frequency band. As shown in this diagram, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately ±60°. In this case, the gain of the multi-frequency antenna 100 is approximately + 1.64 dB compared to a dipole antenna.

[0060] Fig. 22(a) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the lowest frequency f = 1710 MHz of the E-net frequency band. As shown in this diagram, although there is a slight disparity in directionality characteristics between the plus angle direction and the minus angle direction, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately ±60°. In this case, the gain of the multi-frequency antenna 100 is approximately + 4.07 dB compared to a dipole antenna.

[0061] Fig. 22(b) shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the middle frequency f = 1795 MHz of the E-net frequency band. As shown in this diagram, although there is a slight disparity in directionality characteristics between the plus angle direction and the minus angle direction, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately ±60°. In this case, the gain of the multi-frequency antenna 100 is approximately + 2.44 dB compared to a dipole antenna.

[0062] Fig. 23 shows directionality characteristics in a horizontal plane for a multi-frequency antenna 100 at the highest frequency f = 1880 MHz of the E-net fre-

quency band. As shown in this diagram, good directionality characteristics are obtained, having a maximum level at an angle of elevation of approximately +75° and -65°. In this case, the gain of the multi-frequency antenna 100 is approximately + 4.46 dB compared to a dipole antenna.

[0063] As can be seen from the directionality characteristics in the vertical plane illustrated in Fig. 16 to Fig. 23, even if it is supposed that the antenna element 1 is inclined to approximately 76°, the directionality characteristics of the antenna in the vertical plane are such that it radiates in all directions, having a good angle of elevation of approximately ±60°. Moreover, the directionality characteristics in the horizontal plane are virtually omnidirectional characteristics, as illustrated in Fig. 11 to Fig. 14. Thereby, the multi-frequency antenna 100 according to the first embodiment of the present invention can be used suitably as an antenna operating in mobile phone bands.

[0064] Next, Fig. 24 and Fig. 25 illustrate a second embodiment of a multi-frequency antenna according to the present invention.

[0065] In this multi-frequency antenna 200 according to the second embodiment of the present invention, as illustrated in these diagrams, the antenna element 201 is inclined to a greater degree than the antenna element 1 according to the first embodiment. The angle of this inclination is, for example, approximately 50°. The composition of the multi-frequency antenna 200 according to the second embodiment of the present invention has the same composition as the multi-frequency antenna 100 according to the first embodiment, except for the inclination thereof, and hence the inclined composition thereof is described below.

[0066] As shown in Fig. 24, the antenna element 201 stands at an angle of inclination of approximately 50° with respect to the horizontal plane, for example. This inclination is achieved by inclining the metal screw receiving section 202a formed as an insert of the cover section 202, when it is fixed into the cover section 202. In other words, the composition of the antenna element 201 is similar to that of the antenna element 1. However, the length of the D-net element 213 is different to that of the D-net element 13. In this way, the composition of the cover section 202 differs from the composition of the cover section 2, and the composition of the lower element 210 and the E-net element 211 accommodated inside the cover section 202 are also different.

[0067] Fig. 26 shows the composition of a lower element 210 and E-net element 211 in a multi-frequency antenna 200 according to the second embodiment of the present invention. The detailed composition of the lower element 210 is described hereinafter, but it is plate-shaped having a front end section bent to an approximate L shape in cross section by processing a metal plate, and a screw thread section 210d into which a connecting insertion section 212a is screwed is formed in approximately the centre of a connecting section 210a formed at the bent front end section thereof. Moreover, a soldering piece 210b for soldering to a circuit board 221 is formed at the lower end of the lower element 210.

[0068] Furthermore, although the detailed description thereof is described below, the E-net element 211 is formed so as to have an approximately rectangular radiating surface, by processing a metal plate, a connecting piece extending from approximately the centre of one edge thereof being bent in a square U shape, and a holding piece 211a being formed on the front end thereof. This holding piece 211a is inserted into a cutaway window formed in the upper portion of the main member of the lower element 210, and it holds the lower element 210 on either side thereof. By soldering the portion held in this way, the E-net element 211 is affixed to the lower element 210 and also electrically connected thereto. As described hereinafter, this E-net element 211 has an enlarged radiating surface having an approximately rectangular shape in order that it has virtually omnidirectional characteristics in the horizontal plane. Furthermore, either end section of the E net element 211 is bent slightly forwards, and both corner regions of the upper edge thereof are cut away by processing. This is in order that the E-net element 211 can be accommodated in a narrow accommodating space formed by the rear face of the lower element 210 and the side wall of the cover section 202. The bending of the E-net element 211 and the removal of the two corner regions thereof do not affect the directionality characteristics thereof in the horizontal plane.

[0069] In the multi-frequency antenna 200 according to the second embodiment of the present invention, by means of the aforementioned composition, the separated D-net element 213 and D-net lower element 210 are connected when the antenna element 201 is screwed into the cover section 202. In other words, in the multi-frequency antenna 200 according to the second embodiment of the present invention, the D-net antenna is an antenna which operates in a range from the circuit board 221 to the lower end of the choke coil 214. Moreover, the E-net antenna is an antenna which operates in a range from the circuit board 221 to the upper end of the lower element 210. Moreover, the AM/FM band antenna is an antenna which operates in the range from the circuit board 221 to the antenna tip 322. However, it does not resonate in the AM band.

[0070] Next, the detailed composition of the lower element 210 and the E-net element 211 in the multi-frequency antenna 200 of the second embodiment of the present invention will be described with reference to Fig. 27 and Fig. 28.

[0071] Fig. 27 shows the detailed composition of the lower element 210: Fig. 27(a) is a front view of the lower element 210; Fig. 27(b) is a side view thereof; Fig. 27 (c) is a rear face view thereof; and Fig. 27(d) is a lower face view thereof.

[0072] As illustrated in these diagrams, the lower element 210 has a plate shape, the front end section

thereof being bent to an approximate L shape in cross-section, by processing a metal plate. The bent front end section thereof is taken as a connecting section 210a, and a screw thread section 210d into which the connecting insertion section 212a is screwed is formed in the approximate centre of this connecting section 210a. Furthermore, a taper is applied to the main piece 210c extending downwards from the end of the connecting section 210a, such that it has a narrower width at the lower end thereof, and the upper portion thereof is bent slightly towards to the rear side. A soldering piece 210b for soldering to the circuit board 221 is formed at the lower end of the main piece 210c. Moreover, a portion of the upper part of the main piece 210c is cutaway to form cutaway window 210e. The length of the lower element 210 is formed slightly longer than the lower element 10.

[0073] Fig. 28 shows the detailed composition of the E-net element 211: Fig. 28(a) is a front view of the E-net element 211; Fig. 28(b) is a side view thereof; and Fig. 28(c) is a bottom view thereof.

[0074] As shown in these diagrams, the E-net element 211 is formed having an enlarged radiating surface having an approximately rectangular shape, by processing a metal plate, end pieces 211d, 211e on either side being bent slightly forwards on the approximately rectangular radiating surface, and both corner sections of the upper edge thereof being cut away by processing. Moreover, a connecting piece 211f and bent piece 211b are formed by extending a portion from approximately the centre of the upper edge of the element 211, and bending it into a square U shape. A holding piece 211a is formed by cutting one portion of the front edge of the bent piece 211b.

[0075] This holding piece 211a is inserted to sit either side of the cutaway window 210e forming on the upper portion of the main piece 210c of the lower element 210. When thus held, the E-net element 211 can be affixed to the lower element 210, and mutual electrical connection therebetween can be established, by soldering the holding piece 211a about the periphery of the cutaway window 210e. If the bend angle of the central piece 211c with respect to the connecting piece 211f is set to greater than 90° when the E-net element 211 is affixed to the lower element 210, then the lower element 210 and the centre piece 211c of the E-net element 211 will be positioned approximately in parallel, as illustrated in Fig. 26.

[0076] The multi-frequency antenna 200 according to the first embodiment of the present invention operates simultaneously as a four-frequency antenna for D-net and E-net mobile phone bands, and an AM/FM band, and furthermore, GPS signals can be received by means of a separately provided GPS unit 223. In this case, if no AM/FM band devices are provided and hence the AM/FM antenna is obsolete, then it is possible to accommodate only the D-net element 213, which is one of the split elements, inside the antenna base section 230. In this way, the multi-frequency antenna 200 according to the second embodiment of the present invention may be a multi-frequency antenna that operates only in the D-net and E-net by means of the antenna element 201. In this case, naturally, the length of the antenna element 201 can be shorted accordingly.

[0077] Next, the composition of the D-net and E-net antenna in the composition in Fig. 24 will be described, by the following explanation of the basic composition principles of an antenna which is used as a multi-frequency antenna operating only in the D-net and E-net in this manner.

[0078] Fig. 29(a) shows the basic composition of an antenna operating in the D-net and E-net, relating to a multi-frequency antenna 200 according to the second embodiment of the present invention.

[0079] As shown in Fig. 29(a), the split D-net antenna is a linear antenna of length L11, comprising an upper portion forming a D-net element 213, and a lower portion forming a lower element 210 of length L12. Moreover, the D-net antenna composed in this manner projects in a slightly inclined manner at an angle of $\theta 2$ with respect to the horizontal plane. An E-net element 211 having a length L13 is connected to the region where the D-net element 213 joins with the lower element 210. The E-net element 211 is disposed approximately in parallel to the lower element 210, separated therefrom by the length L14 of the connecting piece 211f described above. The front end of this connecting piece 211f is connected to an intermediate part of the D-net antenna constituted by the D-net element 213 and the lower element 210. The composition of the E-net element 211 is as illustrated in Fig. 28, and the approximate form thereof is illustrated in Figs. 29(b) and (c), the width of the rectangular shape forming the enlarged radiating surface being taken as W2. The lower end of the lower element 210 forms an electricity supply point for the D-net antenna and the E-net element 211, as illustrated in the diagrams.

[0080] The dimensions illustrated in Fig. 29, namely, the length L11 of the D-net antenna constituted by the D-net element 213 and lower element 210, the length L12 of the lower element 210, the length L13 and width W1 of the E-net element 211, and the interval L14 between the D-net antenna and the E-net element 211, are determined according to the frequency values of the first frequency band for the D-net and the second frequency band for the E-net, and the angle $\theta 2$ used. For example, if the angle $\theta 2$ is approximately 50°, then the taking the wavelength at the central frequency of the D-net 915 MHz as $\lambda 1$ (327.87 mm) and the wavelength at the central frequency of the E-net 1795 MHz as $\lambda 2$ (167.23 mm), the length L11 of the D-net antenna can be taken as approximately 0.221 $\lambda 1$, the length L12 of the lower element 210 as approximately 0.174 $\lambda 2$, the length L13 of the E-net element 211 as approximately 0.120 $\lambda 2$, the width W2 thereof as approximately 0.149 $\lambda 2$, and the interval L14 between the D-net antenna and the E-net element 211, approximately 0.015 $\lambda 2$.

[0081] The interval L14 is small, as described above, because the accommodation space inside the cover section 202 is narrow, and since this accommodation space is narrow, the width W2 of the E-net element 211 is also small, and the bend angle of the end pieces 211d, 211e becomes tighter. However, the length of the D-net antenna and the E-net element 211 becomes greater.

[0082] The multi-frequency antenna 200 of the second embodiment according to the present invention as illustrated in Fig. 24, has virtually the same characteristics as the multi-frequency antenna 100 relating to the first embodiment, in terms of the impedance characteristics and VSWR characteristics of the multi-frequency antenna 200 in the D-net and E-net frequency bands, taking the aforementioned constants for the dimensions of the lengths, width and interval of the D-net element 213, lower element 210 and E-net element 211. Moreover, the directionality characteristics in the horizontal plane and the directionality characteristics in the vertical plane of the multi-frequency antenna 200 in the D-net and E-net frequency bands in this case are virtually the same as the directionality characteristics of the multi-frequency antenna 100 relating to the first embodiment.

[0083] In the first embodiment and second embodiment of the multi-frequency antenna according to the present invention described above, the E-net elements 11, 211 are formed in such a manner that they have an extended radiating surface having an approximately rectangular shape. This is in order that the directionality characteristics in the horizontal plane are virtually omnidirectional, but if omnidirectional characteristics are not required in the horizontal plane, then the E-net elements 11, 211 made be formed with a narrow width. Moreover, if the widths of the E-net elements 11, 211 are taken as approximately 0.12 $\lambda 2$, or above, then virtually omnidirectional characteristics are obtained in the horizontal plane.

[0084] In the multi-frequency antenna according to the present invention, a second antenna forming an E-net antenna, for example, if connected to the intermediate portion of a first antenna forming a D-net antenna, for example. It is inferred that the fact that the two antennas operate without causing mutual adverse effects when composed in this manner is related to the fact that the second antenna operates in a frequency band approximately twice as high as the frequency band in which the first antenna operates.

INDUSTRIAL APPLICABILITY

[0085] Since the present invention is composed in the foregoing manner, a second element having an extended rectangular radiating surface operating in a second frequency band which is higher than a first frequency band is connected at an intermediate region of a first element operating at the first frequency band. By adopting this composition, although the operational principles are not evident, the antennas are able to operate independently without mutual adverse effects, even across a first frequency band and a second frequency band covering a broad frequency band such as mobile phone bands. Since the radiating surface of the second element is extended, it is possible to achieve omnidirectional characteristics in the horizontal plane.

[0086] In this case, the first element used for a low frequency band is split into two, the split lower element being accommodated inside a cover section, whilst a second element is also accommodated inside the cover section, whereby a compact multi-frequency antenna can be achieved. It is also possible to accommodate a circuit board incorporating a frequency divider, and the like, in the space inside the cover section.

[0087] Moreover, by providing a element operating in a very low frequency band, such as an AM/FM band, via a choke coil at the upper end of the first element, it is possible to achieve a multi-frequency antenna operating at three or more frequencies. Furthermore, if a GPS antenna unit is provided in the accommodating space inside the cover, it is possible to receive GPS signals, without affecting the other antennas.

Claims

1. A multi-frequency antenna **characterized in that** it comprises:

    a first element operating in a first frequency band; and
    a second element having a rectangular extended radiating surface, operating in a second frequency band which is higher than said first frequency band.

2. The multi-frequency antenna according to claim 1, **characterized in that** said first frequency band is taken as a first mobile radio band, and said second frequency band is taken as a second mobile radio band, being a frequency band approximately twice as high as said first mobile radio band.

3. The multi-frequency antenna according to claim 1, **characterized in that** said multi-frequency antenna comprises:

    an upper element of said first element that is split in two; and
    a cover section provided with an connecting section to which said upper element is mounted detachably and with an installing section for installing same onto an installation receiving object;
    the other, lower element of said split first element provided between said connecting section and a power supply section, and said second element connected to said upper portion of

said second lower element, being accommodated inside said cover section, and said upper element and said lower element are mutually connected by mounting said upper element onto said connecting section.

4. The multi-frequency antenna according to claim 3, **characterized in that** a third element operating in a much lower frequency band than said first frequency band is provided at the top end of said upper element, via a choke coil.

5. The multi-frequency antenna according to claim 3, **characterized in that** a GPS antenna unit is also provided inside said cover section.

6. The multi-frequency antenna according to claim 4, **characterized in that** a GPS antenna unit is also provided inside said cover section.

Amended claims under Art. 19.1 PCT

1. **(deleted)**

2. **(deleted)**

3. (amended) A multi-frequency antenna comprising a first element operating in a first frequency band and a second element, connected to an intermediate region of said first element, having a rectangular extended radiating surface and operating in a second frequency band which is higher than said first frequency band; **characterized in that** it comprises:

an upper element of said first element, said first element being split into two elements; and
a cover section provided with a connecting section onto which said upper element can be installed detachably, and an installing section for installing same onto an installation receiving object;
the other, lower element of said split first element provided between said connecting section and a power supply section, and said second element connected to said upper element, being accommodated inside said cover section, and said upper element and said lower element being mutually connected by installing said upper element onto said connecting section.

4. The multi-frequency antenna according to claim 3, **characterized in that** a third element operating in a much lower frequency band than said first frequency band is provided at the top end of said upper element, via a choke coil.

5. The multi-frequency antenna according to claim 3, **characterized in that** a GPS antenna unit is also provided inside said cover section.

6. The multi-frequency antenna according to claim 4, **characterized in that** a GPS antenna unit is also provided inside said cover section.

Fig. 1

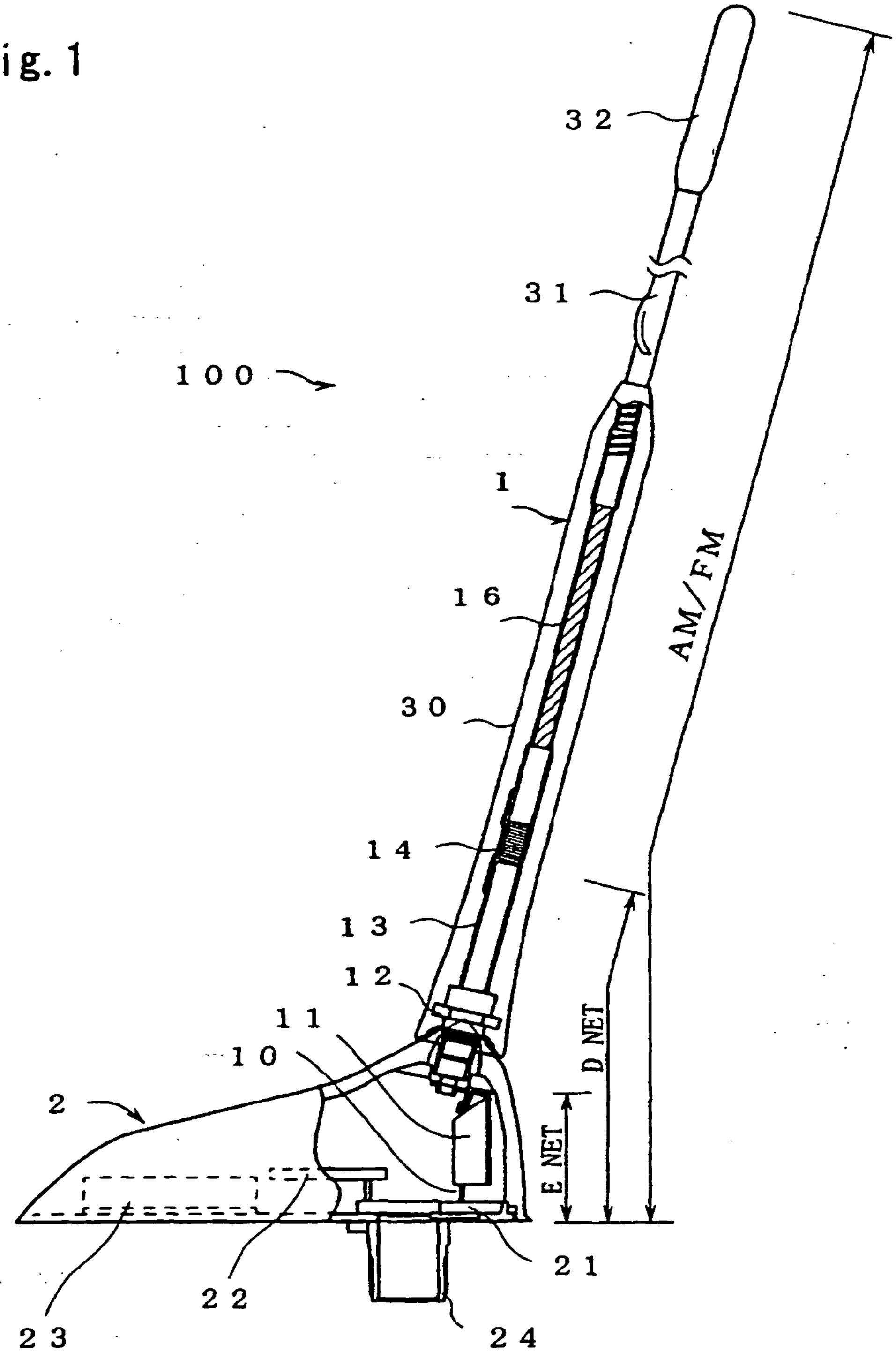


Fig. 2

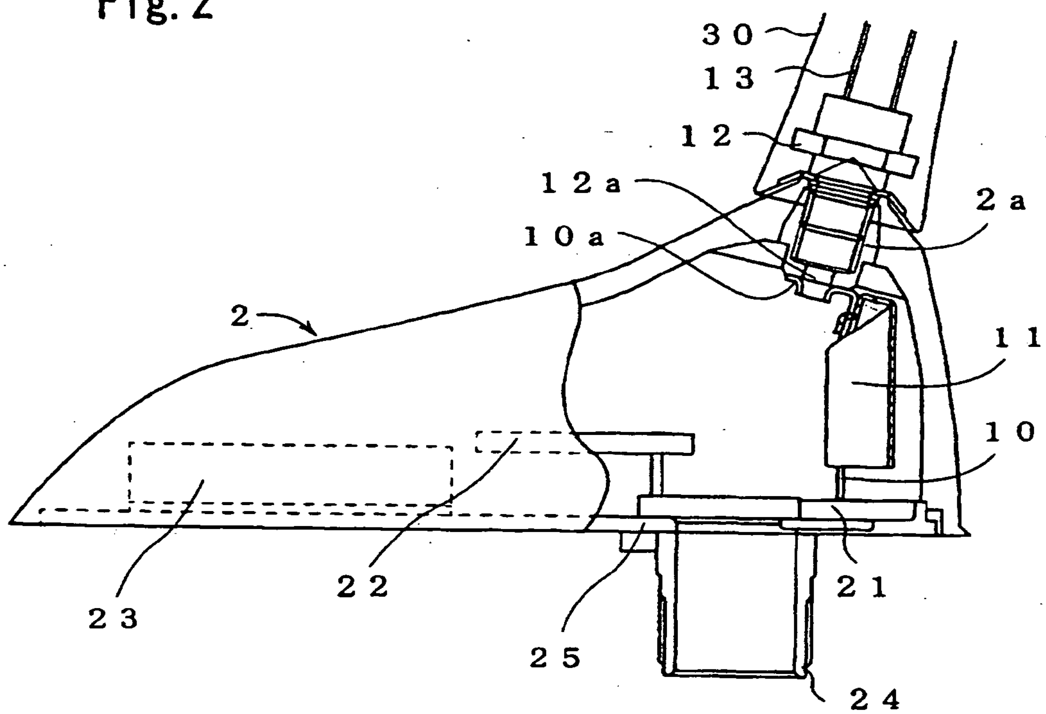


Fig. 3a

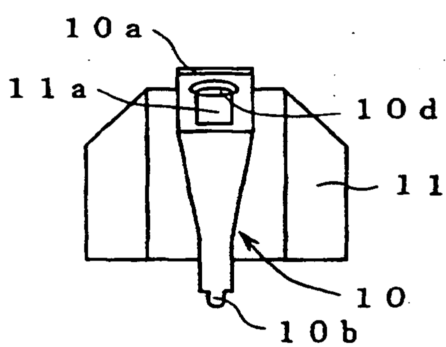


Fig. 3b

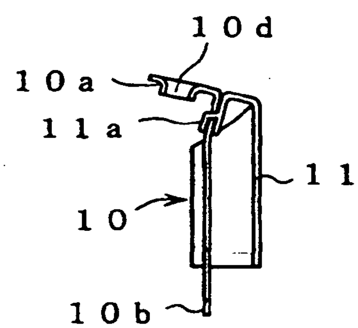


Fig. 4a

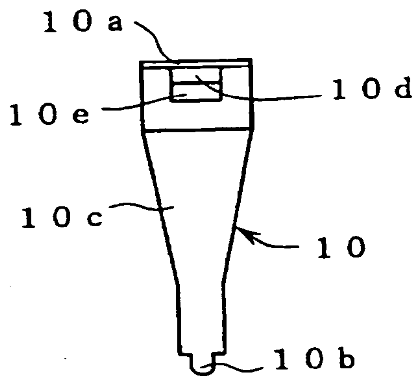


Fig. 4b

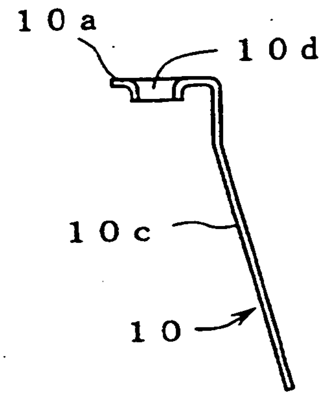


Fig. 4c

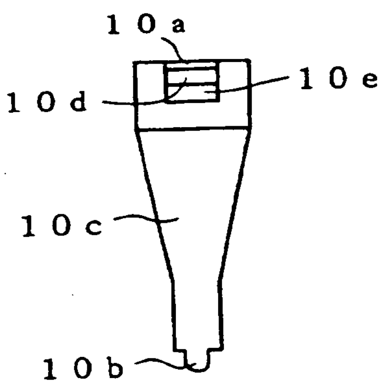


Fig. 4d

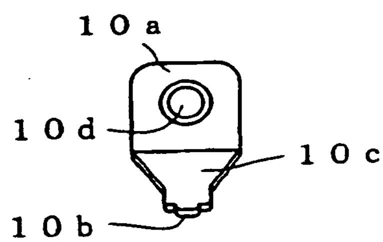


Fig. 5a

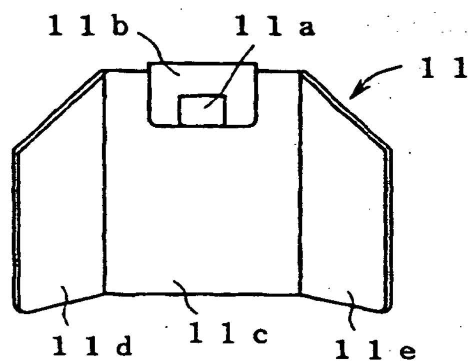


Fig. 5b

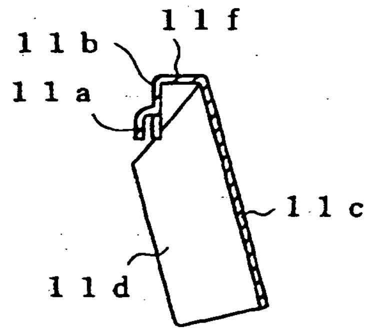


Fig. 5c

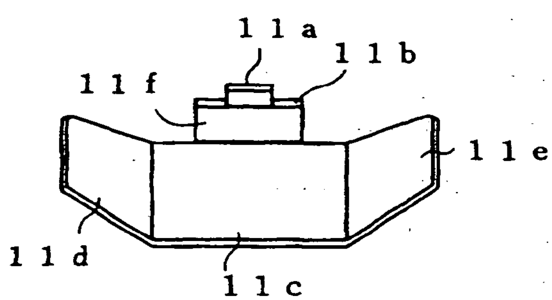


Fig. 6a

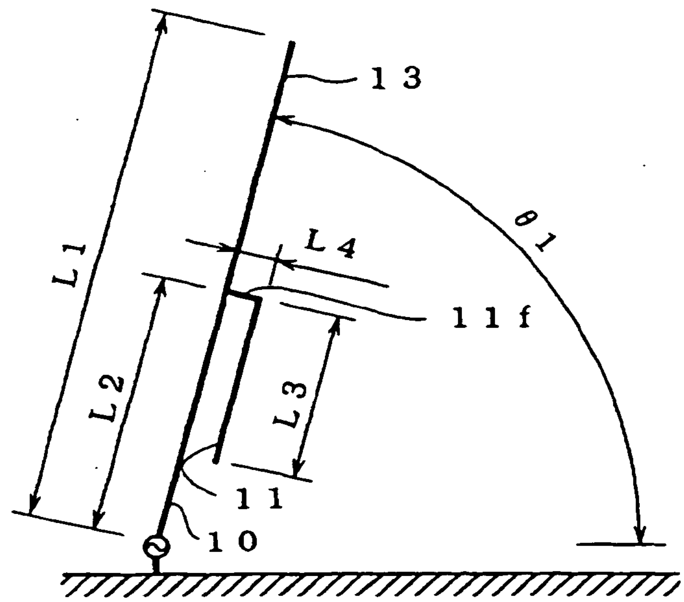


Fig. 6b

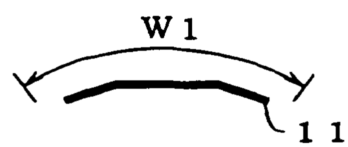


Fig. 6c

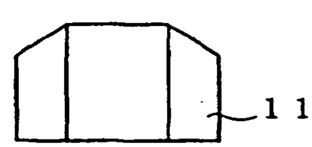
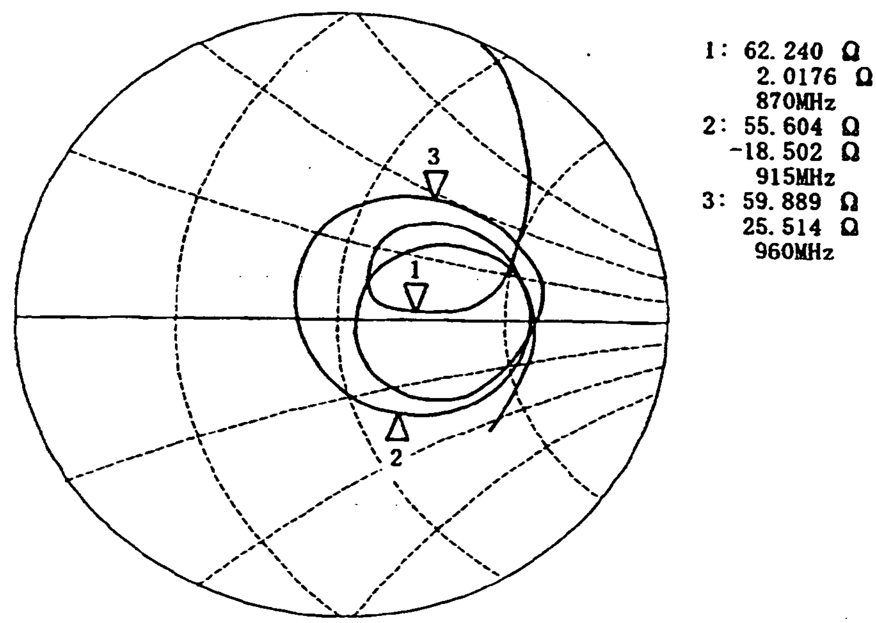


Fig. 7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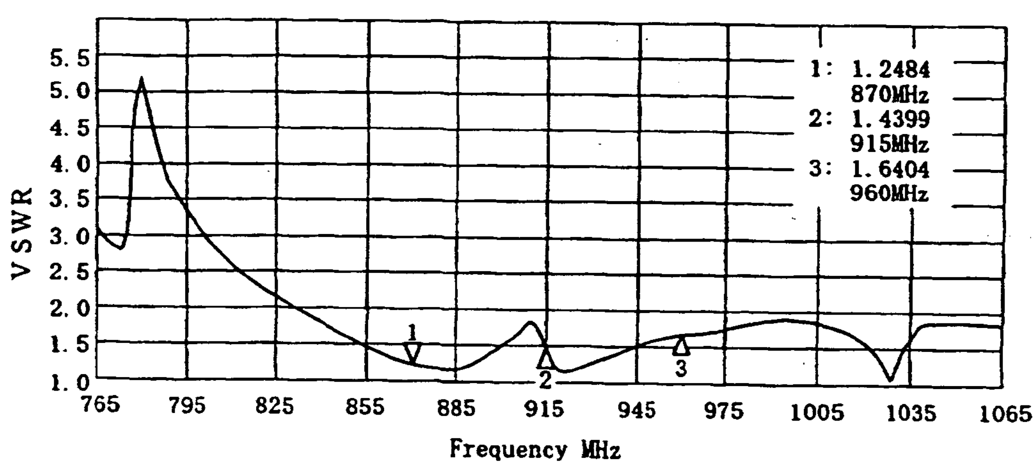
2: 55.604 Ω
-18.502 Ω
915MHz
3: 59.889 Ω
25.514 Ω
960MHz

Fig. 8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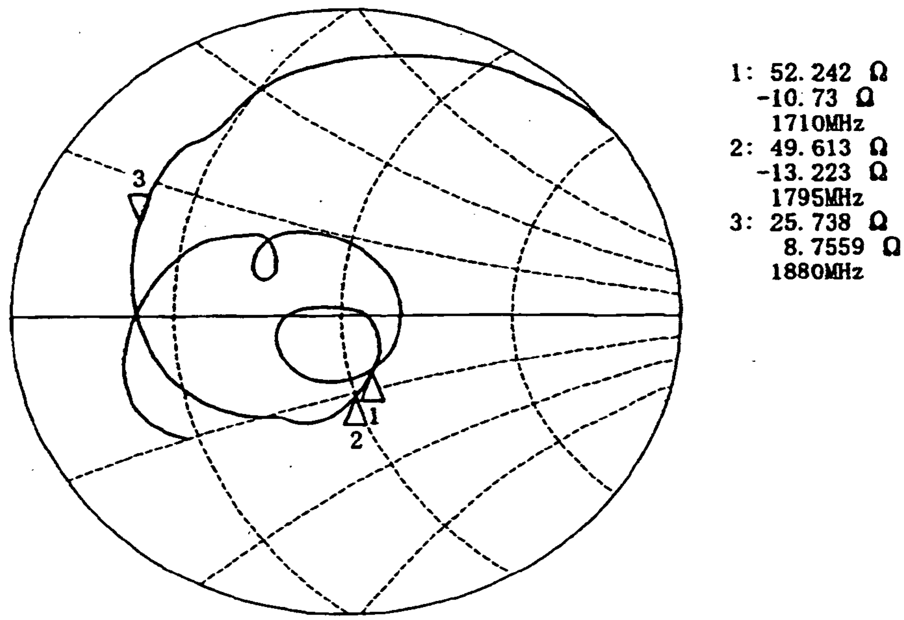
870MHz
2: 1.4399
915MHz
3: 1.6404
960MHz
VSWR
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
765
795
825
855
885
915
945
975
1005
1035
1065
Frequency MHz

Fig. 9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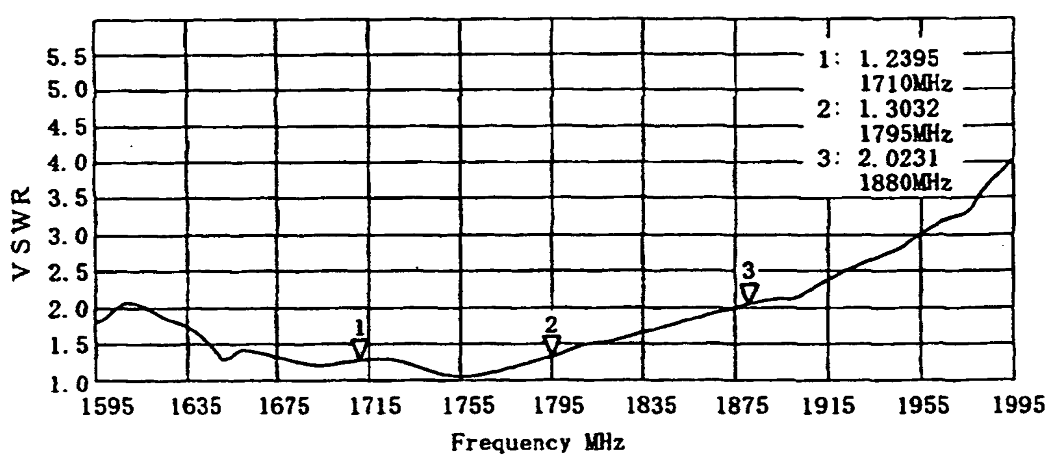
-10.73 Ω
1710MHz
2: 49.613 Ω
-13.223 Ω
1795MHz
3: 25.738 Ω
8.7559 Ω
1880MHz
1
2
3

Fig. 10


5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
VSWR
1595
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1675
1715
1755
1795
1835
1875
1915
1955
1995
Frequency MHz
1: 1.2395
1710MHz
2: 1.3032
1795MHz
3: 2.0231
1880MHz
1
2
3

Fig. 11a

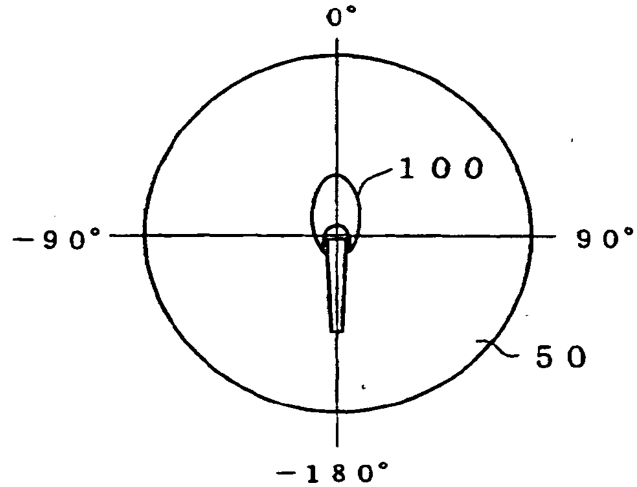
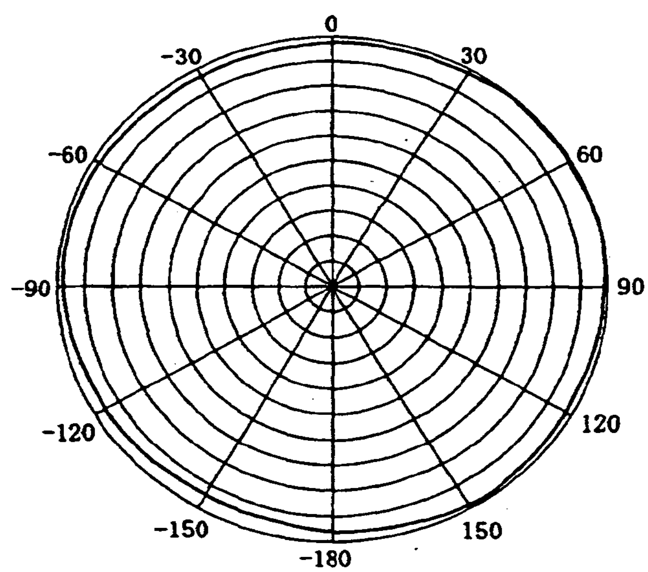
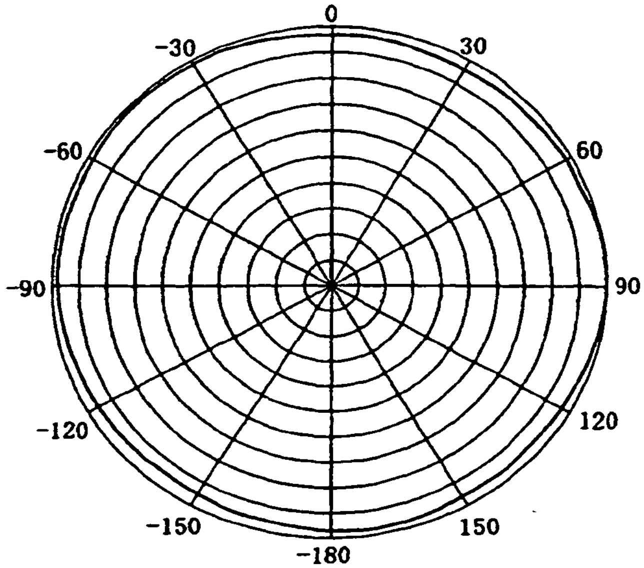


Fig. 11b



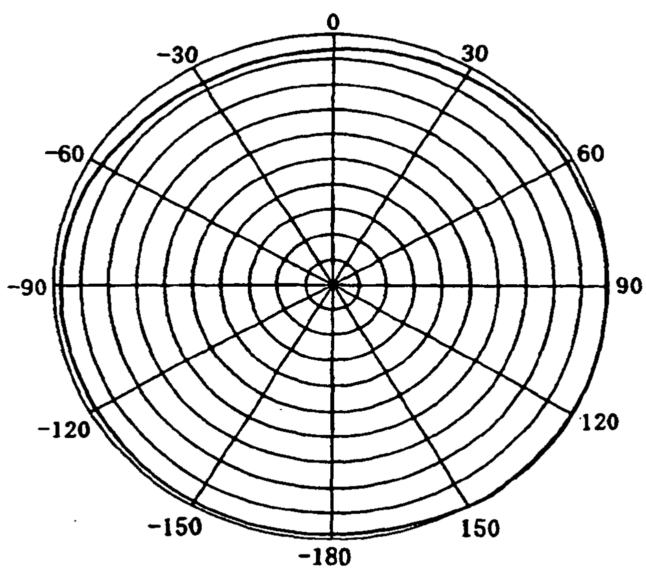
f = 870MHz
GAIN +0. 94dB

Fig. 12a



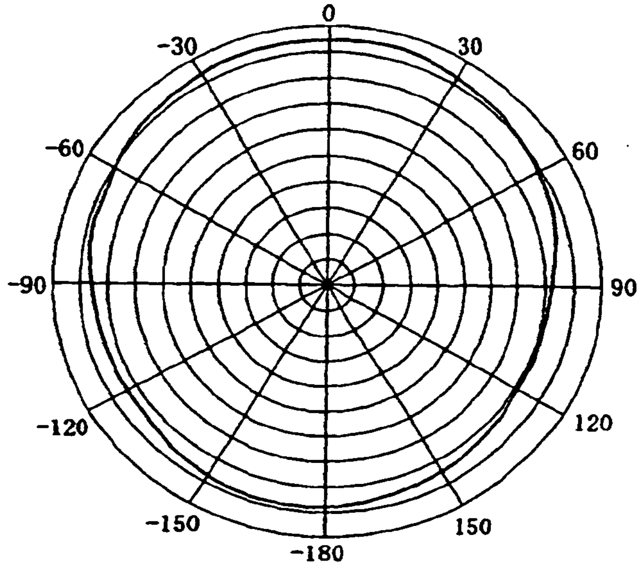
f = 915MHz
GAIN +0. 5dB

Fig. 12b



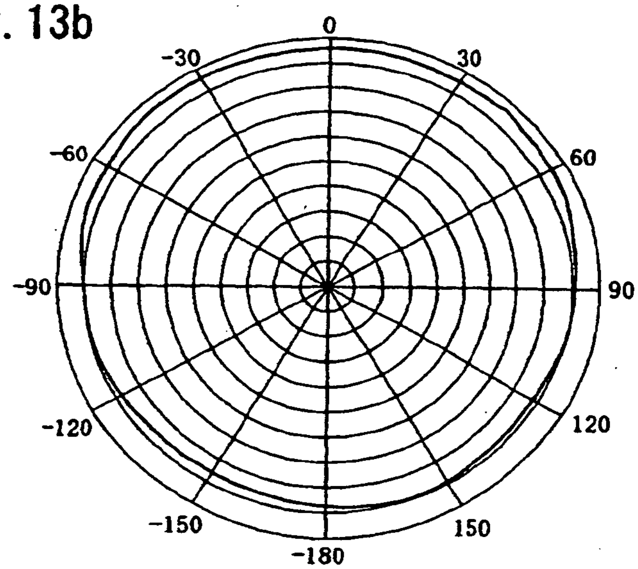
f = 960MHz
GAIN +0. 35dB

Fig. 13a



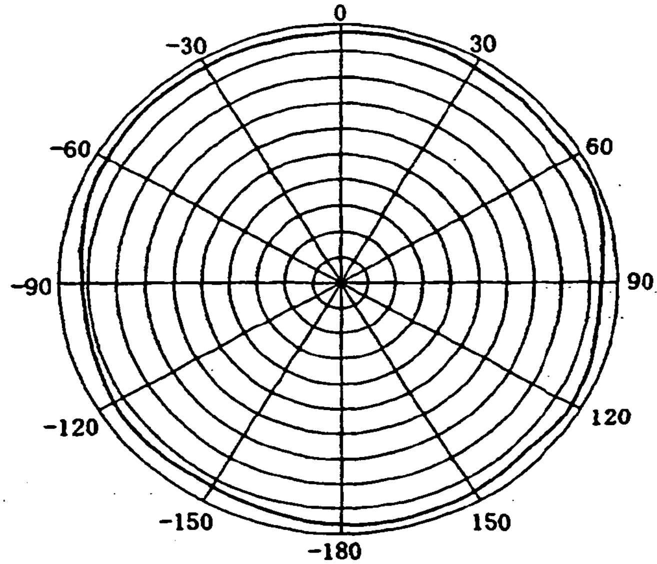
f = 1 7 1 0MHz
GAIN −0. 8dB

Fig. 13b



f = 1 7 9 5MHz
GAIN −0. 6dB

Fig. 14



f = 1 8 8 0MHz
GAIN +0. 3dB

Fig. 15

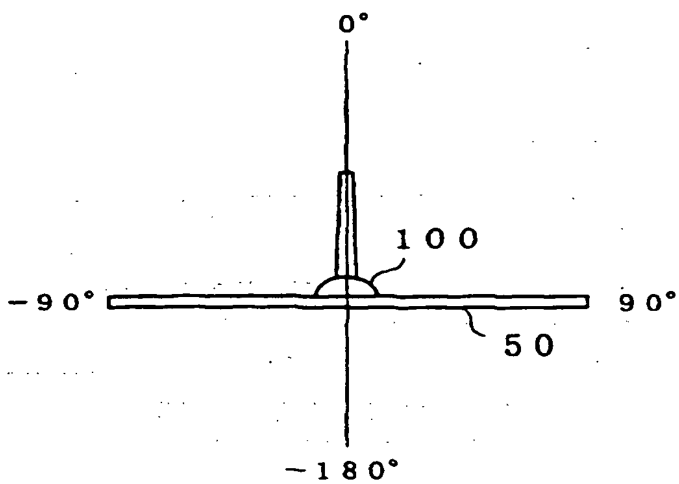
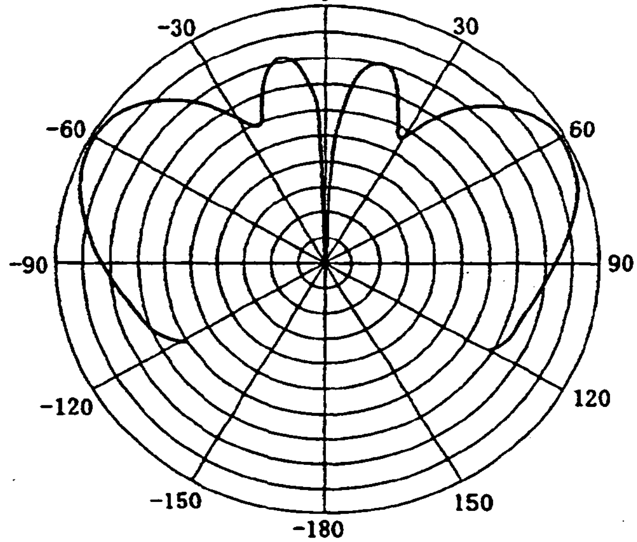
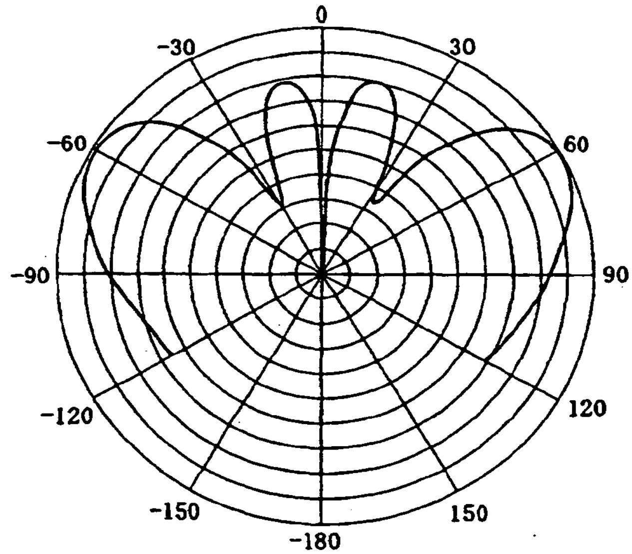


Fig. 16a



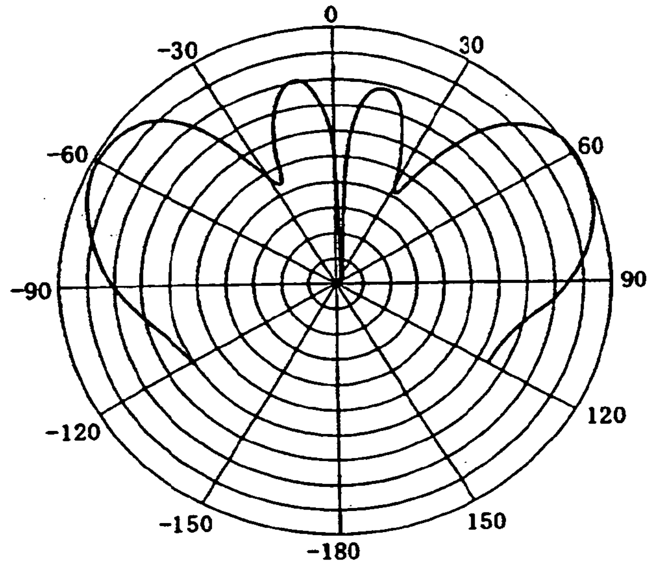
f = 870MHz
GAIN +1. 65dB (d)

Fig. 16b



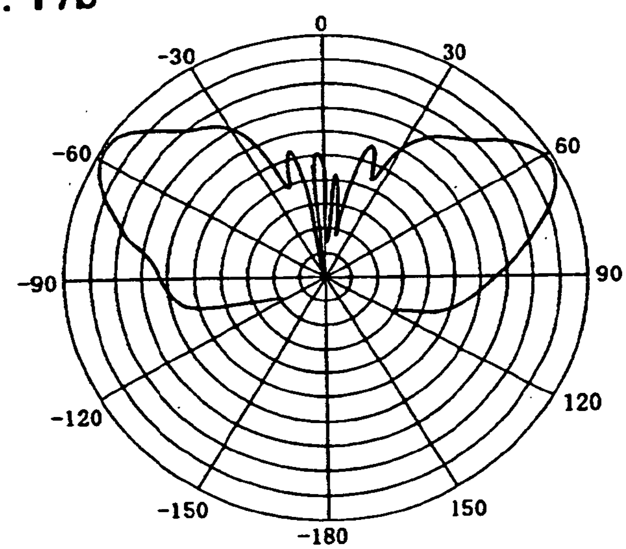
f = 915MHz
GAIN +0. 55dB (d)

Fig. 17a



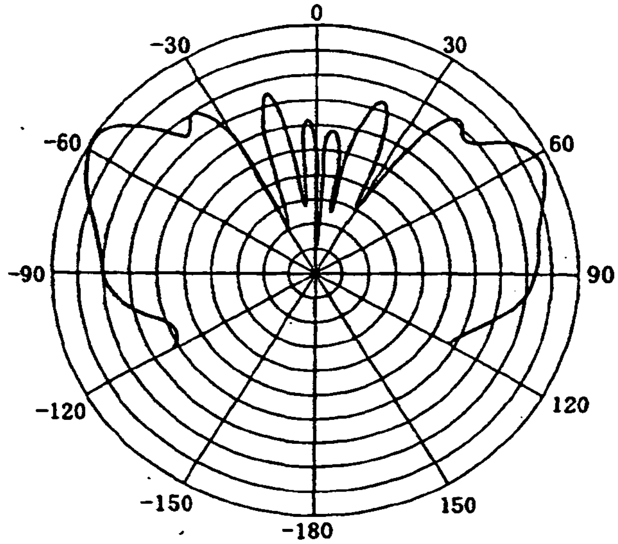
f = 960MHz
GAIN +1. 1dB (d)

Fig. 17b



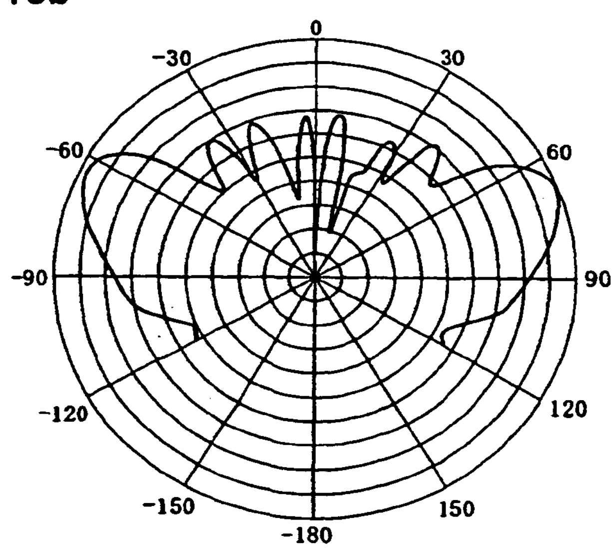
f = 1710MHz
GAIN +3. 98dB (d)

Fig. 18a



f = 1 7 9 5 MHz
GAIN +0. 0 4 dB (d)

Fig. 18b



f = 1 8 8 0 MHz
GAIN +2. 6 5 dB (d)

Fig. 19

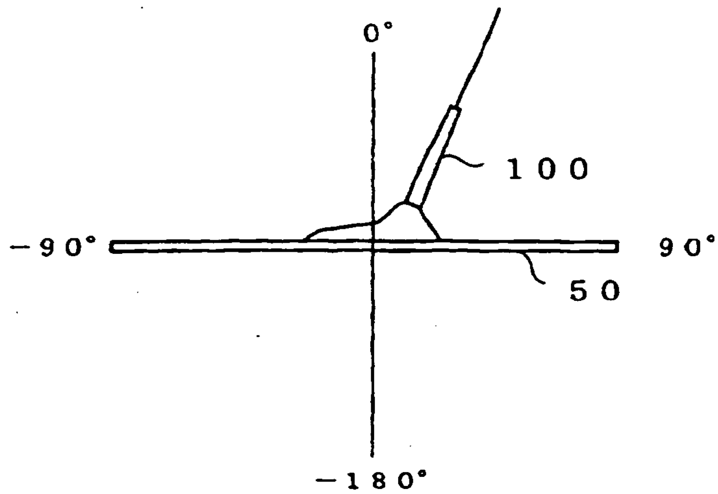
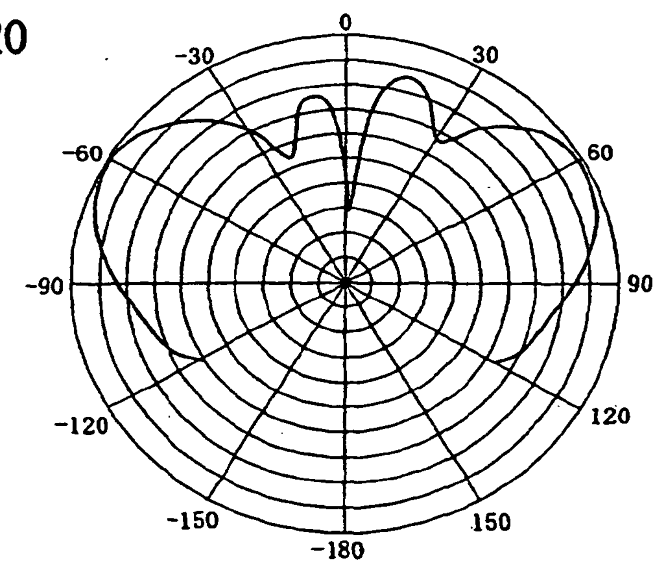
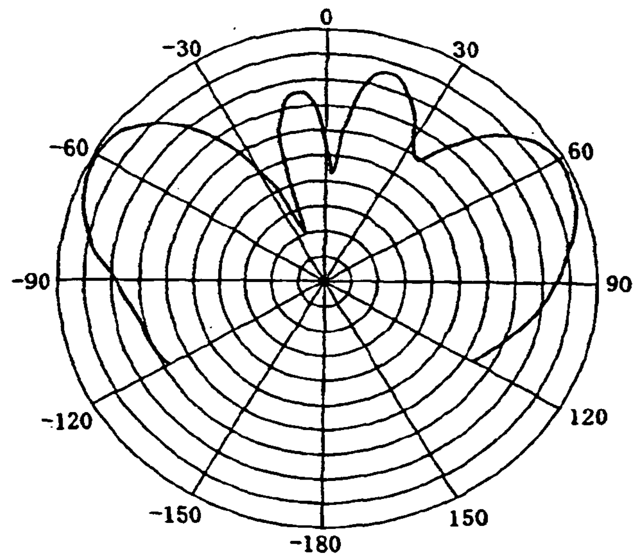


Fig. 20



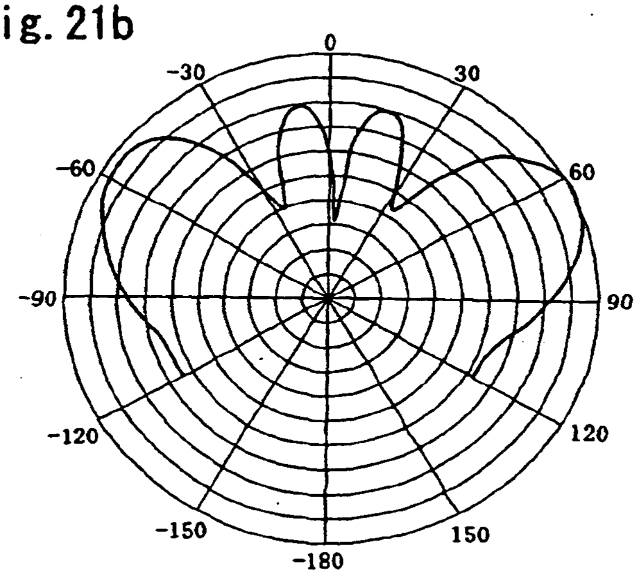
f = 870MHz
GAIN +1.67dB (d)

Fig. 21a



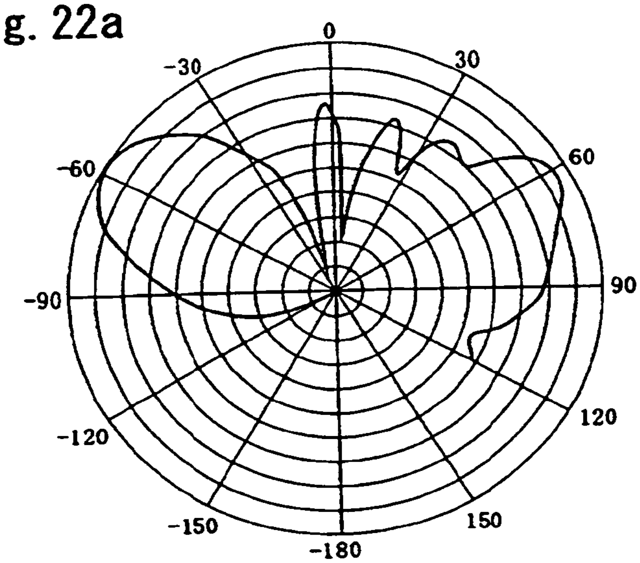
f = 915MHz
GAIN +0. 47dB (d)

Fig. 21b



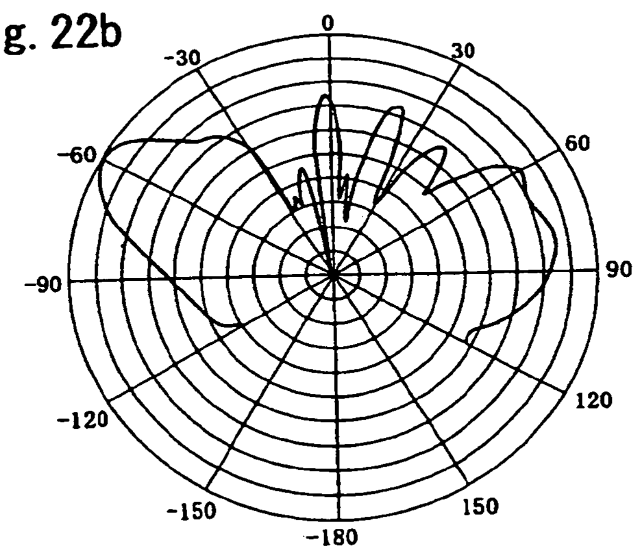
f = 960MHz
GAIN +1. 64dB (d)

Fig. 22a



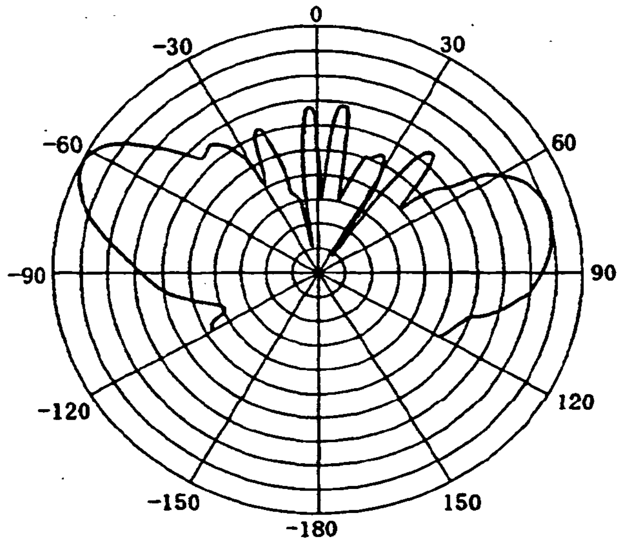
f＝1 7 1 0MHz
GAIN +4. 0 7dB (d)

Fig. 22b



f＝1 7 9 5MHz
GAIN +2. 4 4dB (d)

Fig. 23



f = 1 8 8 0 MHz
GAIN +4. 4 6 dB (d)

Fig. 24

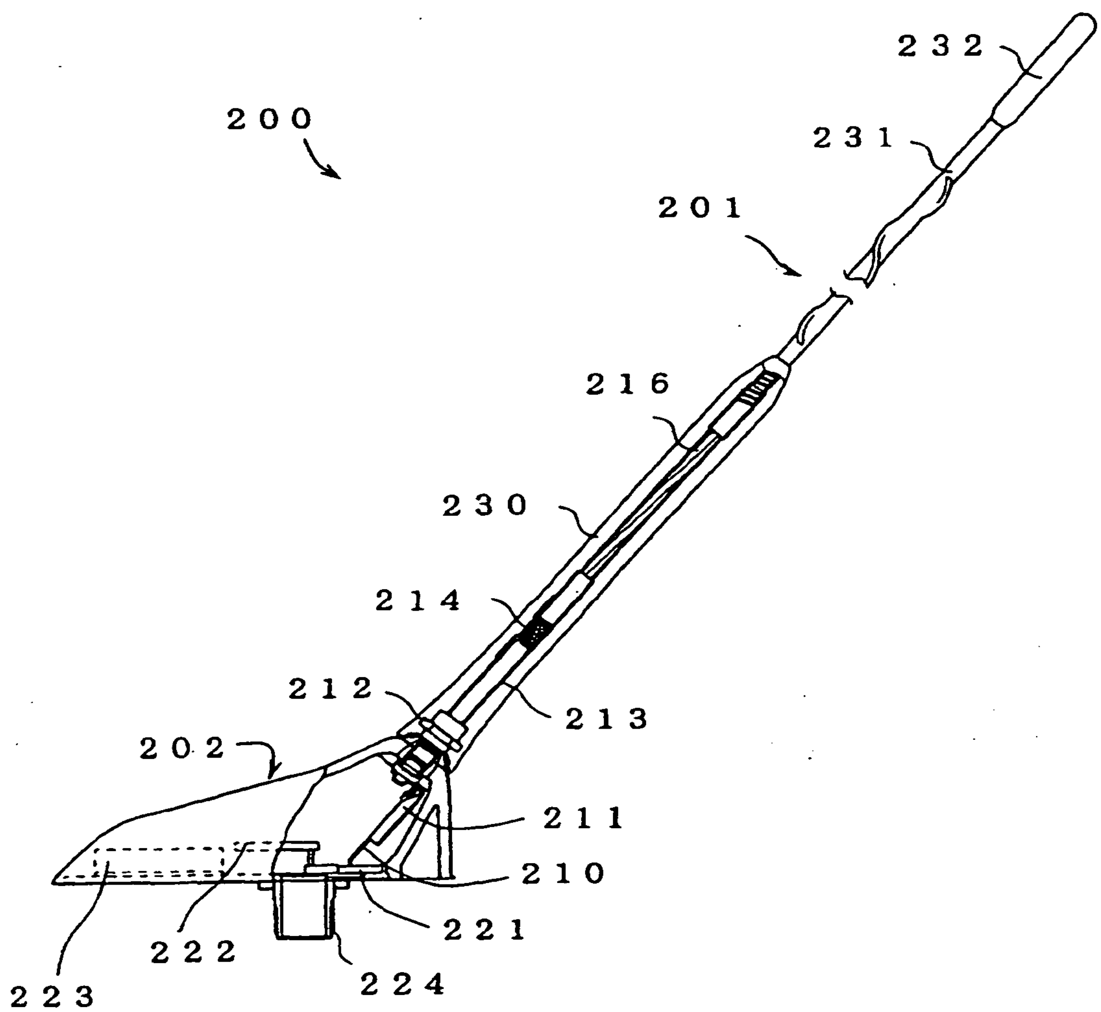


Fig. 25

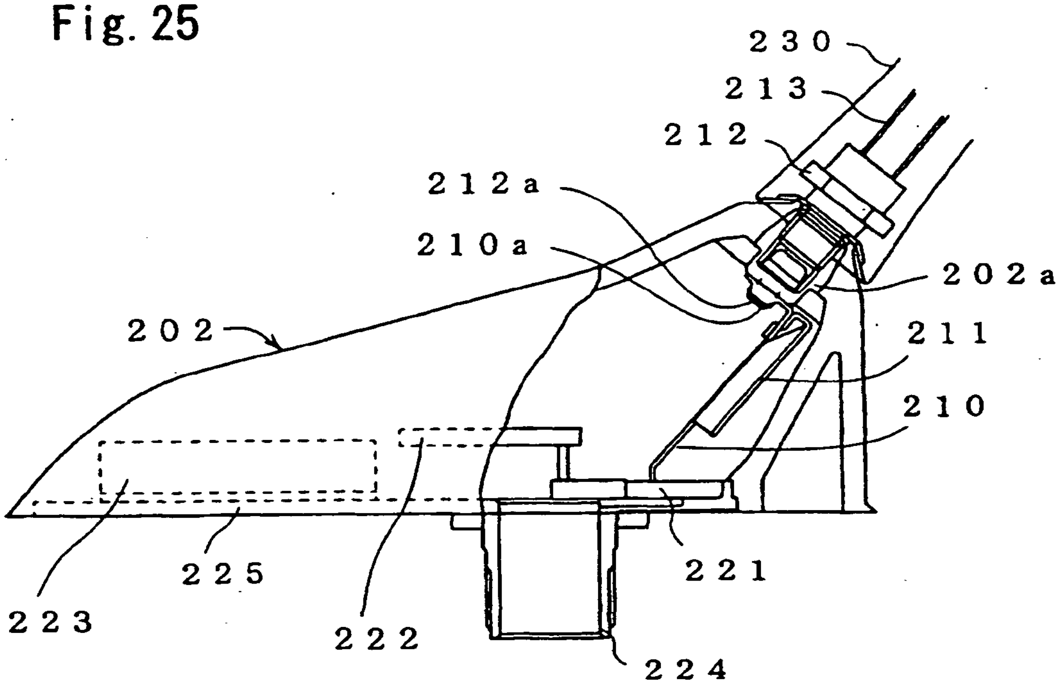


Fig. 26a

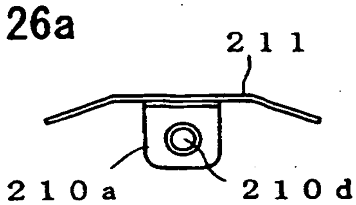


Fig. 26b

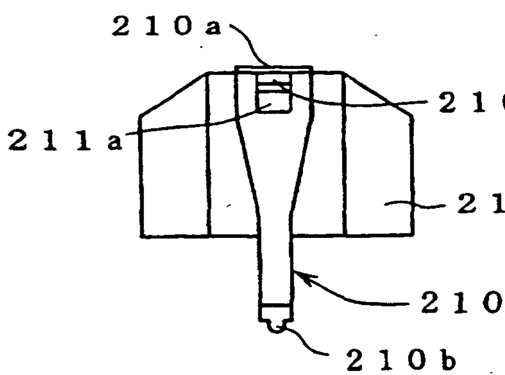


Fig. 26c

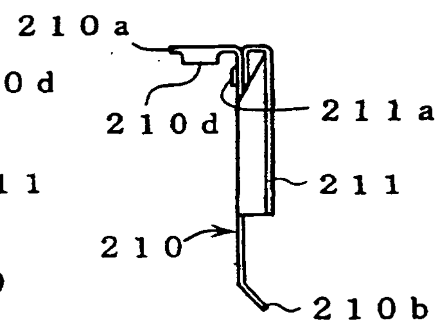


Fig. 27a

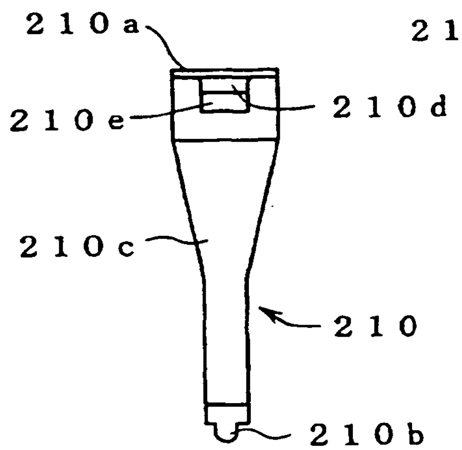


Fig. 27b

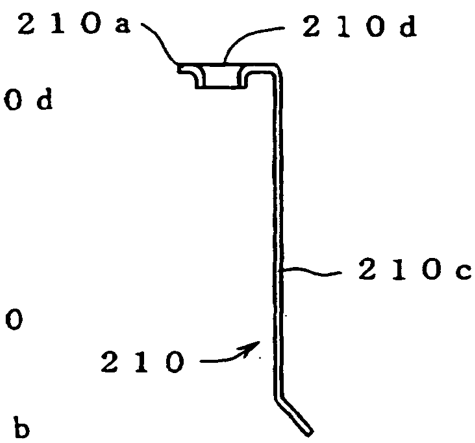


Fig. 27c

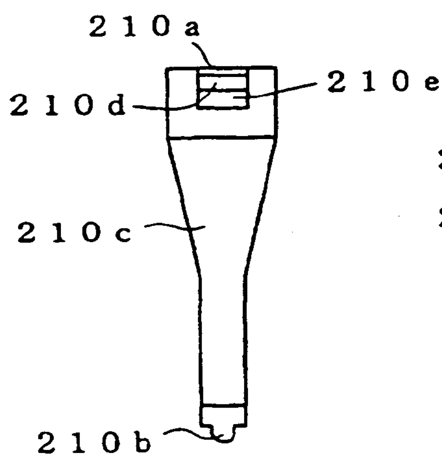


Fig. 27d

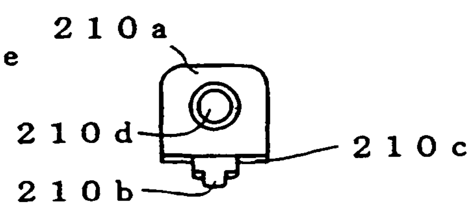


Fig. 28a

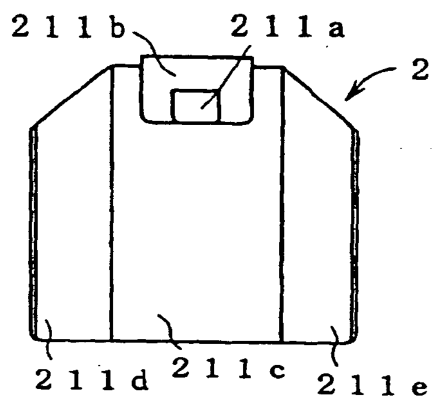


Fig. 28b

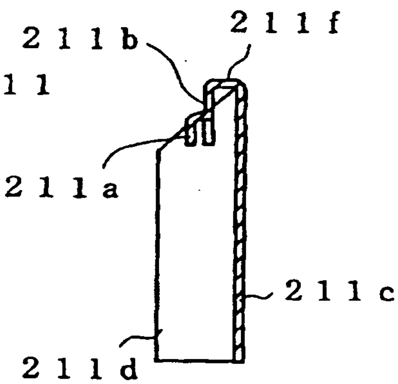


Fig. 28c

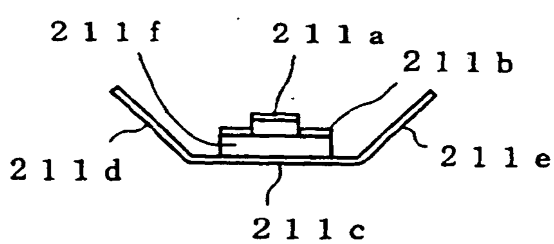


Fig. 29a

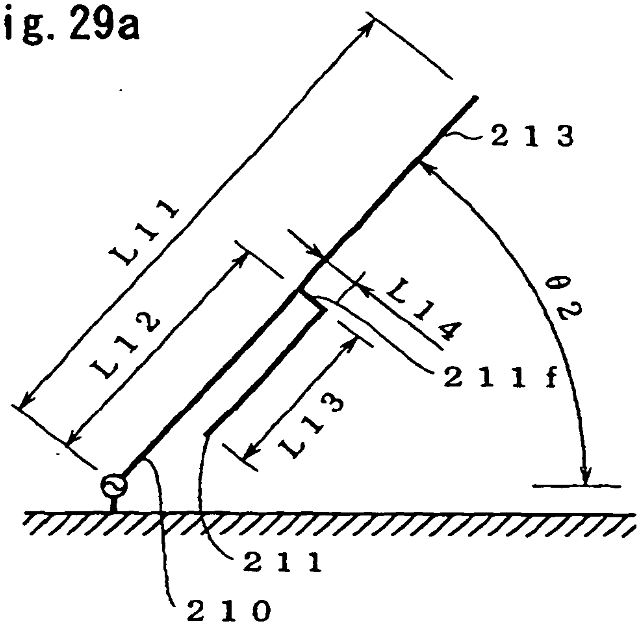


Fig. 29b

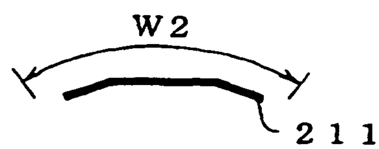
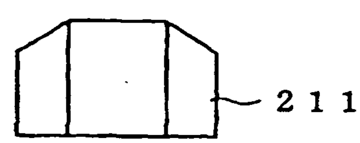


Fig. 29c



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP01/01362

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] H01Q1/32, H01Q5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] H01Q1/32, H01Q5/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-2001
Kokai Jitsuyo Shinan Koho 1971-2001 Jitsuyo Shinan Toroku Koho 1996-2001

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP, 08-204431, A (NTT Ido Tsushinmo K.K.), 09 August, 1996 (09.08.96) (Family: none) Full text; all drawings	1,2 3-6
X A	JP, 11-068453, A (Uniden Corporation), 09 March, 1999 (09.03.99) (Family: none) Full text; all drawings	1,2 3-6
A	Microfilm of Japanese Utility Model Application No. 22417/1987 (Laid-open No.129308/1988), (Toyota Motor Corporation), 24 August, 1988 (24.08.88) (Family: none) Full text; all drawings	1-6
A	JP, 08-335824, A (Harada Ind. Co., Ltd.), 17 December, 1996 (17.12.96) (Family: none) Full text; all drawings	1-6
	Toroku Jitsuyo Shinan Koho No. 3058480	

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search
14 May, 2001 (14.05.01)

Date of mailing of the international search report
22 May, 2001 (22.05.01)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP01/01362

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	(Yaesu Musen K.K.), 10 March, 1999 (10.03.99) (Family: none)	
A	Full text; all drawings	1-6

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